CLIC Accelerating Structure Progress

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1-2-2007

There have been some changes to CLIC parameters

We now have gradient and frequency of

100 MV/m and 12 GHz

which, if our logic is good, already amounts to some progress....

Why 12 GHz rather than 30 GHz?

Gradient appears to be remarkably independent of frequency for a fixed geometry and pulse length.

A lower frequency allows us to access higher-gradient potential geometries, smaller a/λ, more efficiently.

X-band is the an oasis in data, technology and collaborators

Why 100 MV/m rather than 150 MV/m?

We face a feasibility demonstration deadline of 2010

30 GHz didn't bring us any gain,

New materials have shown good potential but are complicated – not mature (yet).

X-band structures operate in the 100 MV/m range and we now understand enough about rf constraints and optimization to use them in these conditions.

It's cheaper and more efficient to use a lower gradient – really!

Why do we think we can get 100 MV/m when NLC/JLC did 55 MV/m?

Smaller aperture structures, tighter alignment tolerances we learned about from life at 30 GHz.

Two-beam scheme does short pulses much better than klystron/rf pulse compressor and we have the strong damping technology to go with it.

Progress has occurred over the past few years,

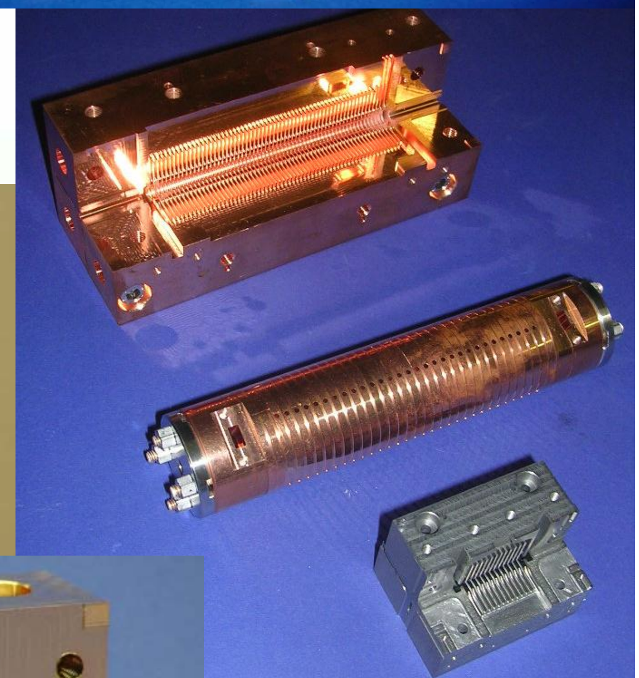
… and this is our goal for 2010!

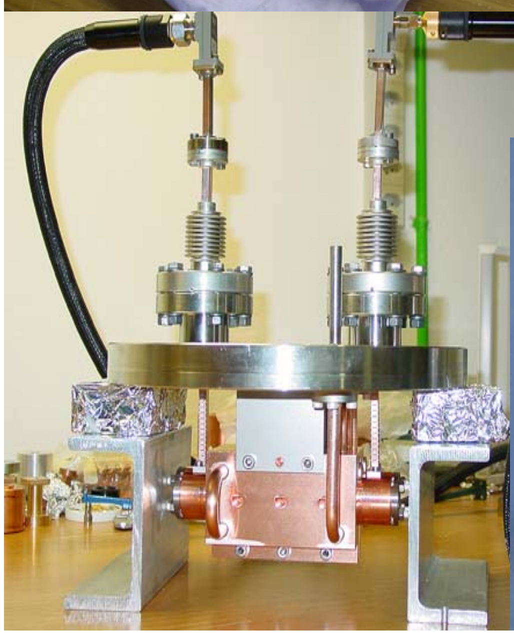
Quite some work to adapt to these changes

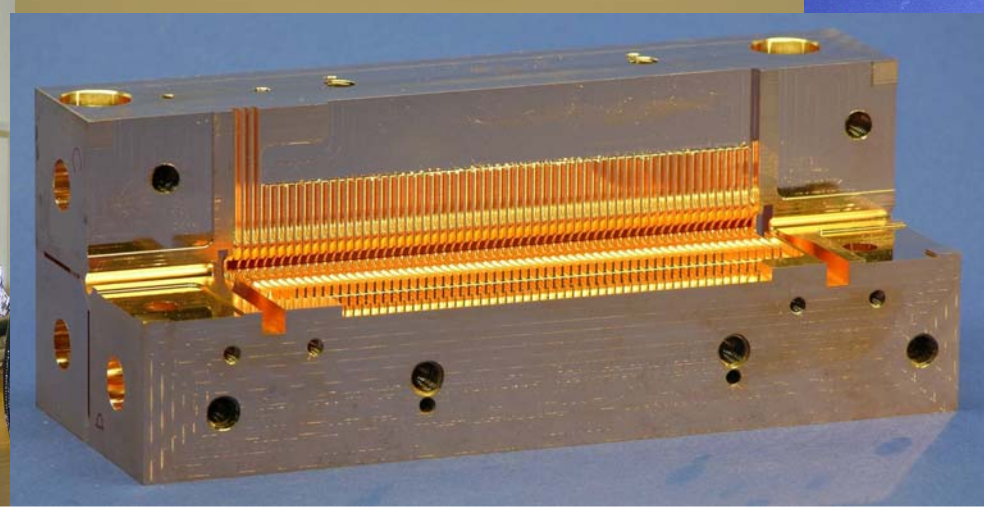
Full parameter study is underway,

In the mean time the presentations at the meetings which lead to the decision can be found on the CLIC web pages, under parameters working group

Modification of test program – current 30 GHz testing continues at least until 12 GHz available in CTF3. Strengthen collaboration with those groups with X-band equipment, testing capacity.







Structures

Main experimental facilities used by CLIC

breakdown

CTF3 30 GHz mid-linac test stand
dc spark set-up
11.424 GHz klystron facilities at SLAC
CTF3 12 GHz two-beam test stand

And

pulsed surface heating

pulsed laser fatigue set-up
ultrasonic fatigue
11.424 GHz klystron facilities at SLAC
Dubna FEM

What can influence the gradient, I

rf design –
Some structure designs will give a higher gradient than others, everything else being constant.
We have a partial understanding of effect of geometry on gradient.
Apparently low surface fields and power flows (over circumference) increase gradient.
So for example a small aperture is good for gradient BUT bad for beam.
Quantitative dependence of gradient on geometry needed to optimize acceleration/emittance growth/efficiency.

rf pulse length –
The shorter the better BUT bad for efficiency. Strong higher order mode damping needed to recuperate efficiency BUT damping features may reduce gradient. Again a quantitative dependence of gradient on geometry is needed to optimize damping features along with a clear knowledge of pulse length dependence.

rf frequency –
Observed dependence at lower frequencies, but apparently little difference between 11 and 30 GHz.

What can influence the gradient, II

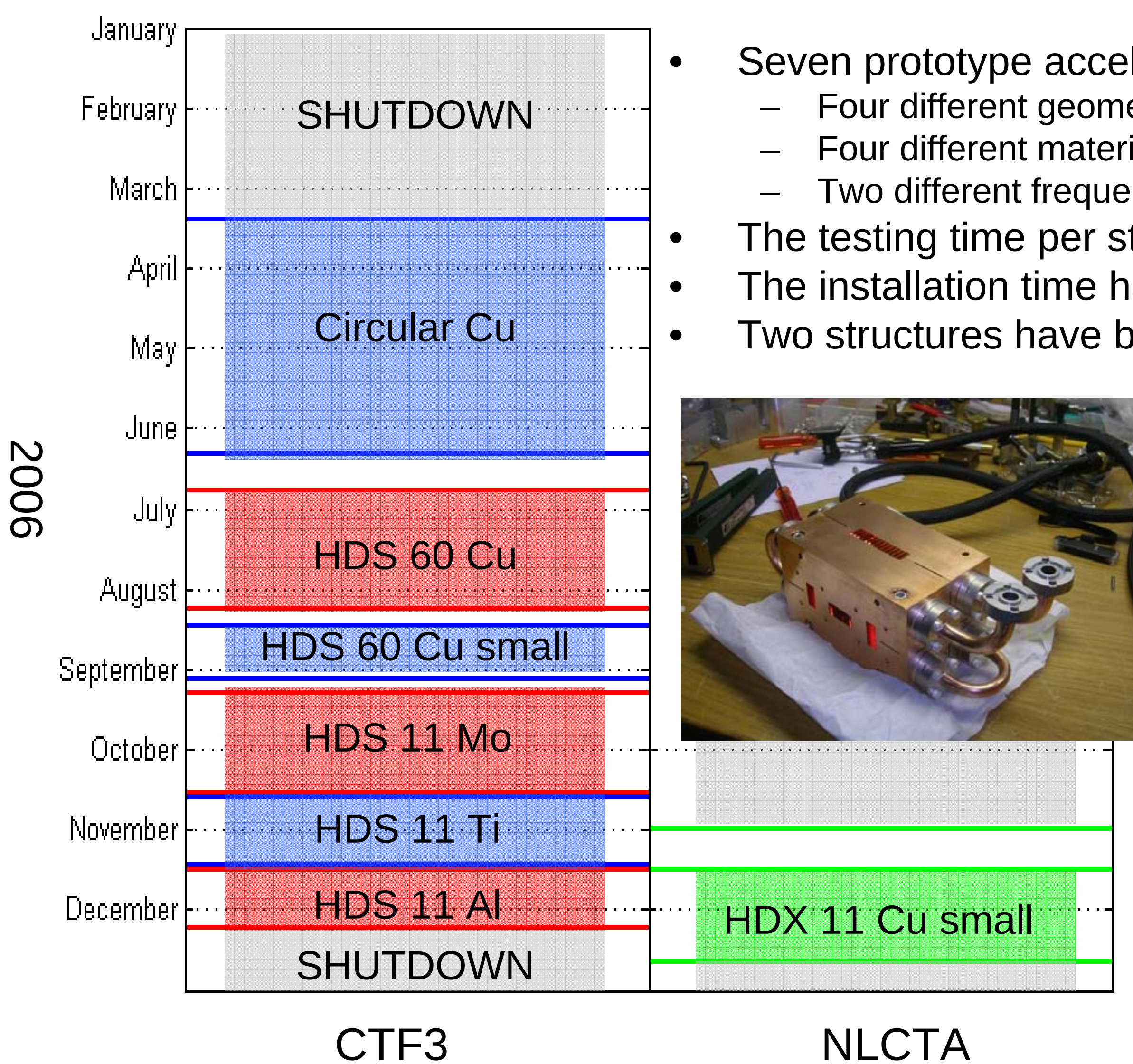
Material –
Copper is an excellent material but can we do better? Change inevitably imposes compromise on electrical and thermal conductivities and technological complexity. We have investigated refractory metals and light metals. Material dependence is complex. Issues include peak gradient, erosion, **breakdown rate** dependence…

Preparation –
Bulk material purity, machining and surface finish, heat treatment, chemical cleaning, other cleaning, conditioning strategy. Each is highly material dependent.

Vacuum level –
Either direct action of gas in triggering or evolving breakdown or influence on surface chemistry.

Other stuff –
Breakdown rate, Temperature, ?

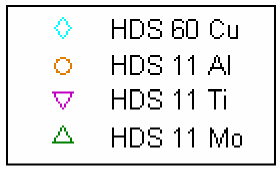
The Structures tested in 2006

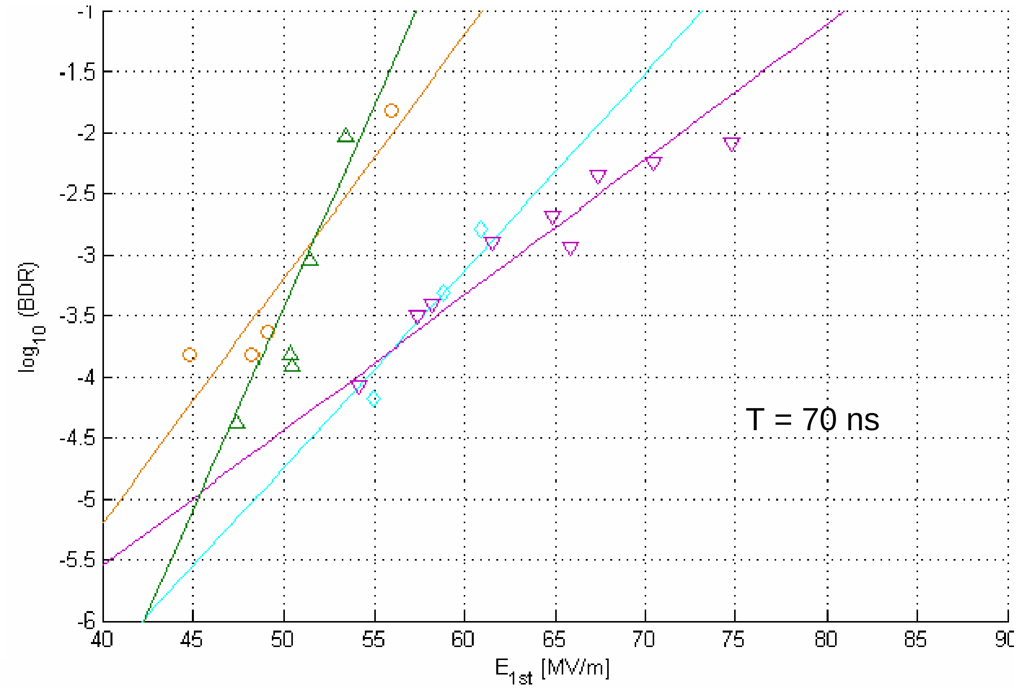


- Seven prototype accelerating structures were tested:
  - Four different geometries (Circular, HDS 11,HDX 11, HDS 60)
  - Four different materials (Cu, Al, Ti, Mo)
  - Two different frequencies
- The testing time per structure has been reduced
- The installation time has also been reduced
- Two structures have been tested at the same time

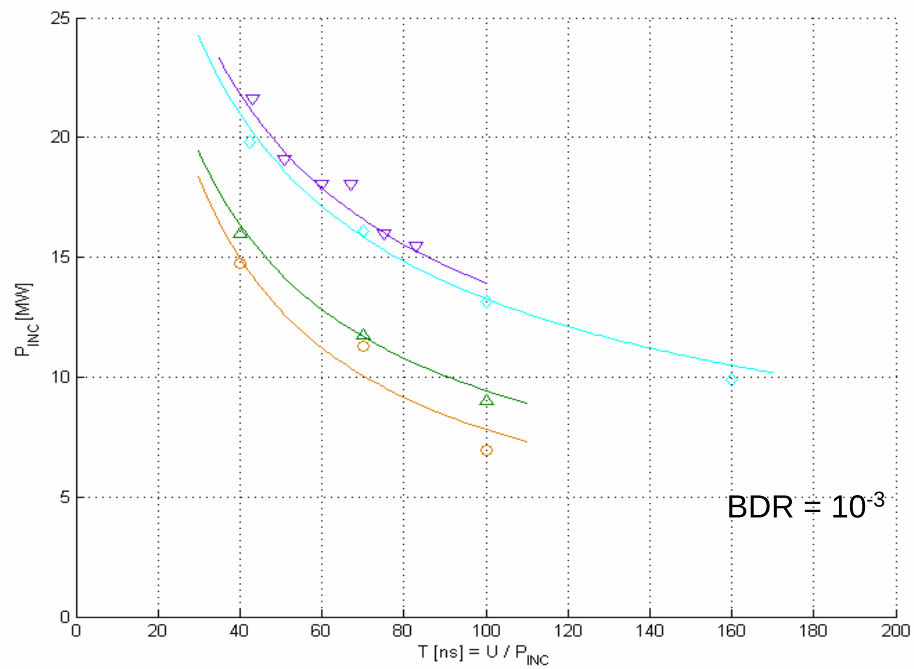
Material

n.b. relative performance of Cu and Mo NOT consistent with past tests, suspect mistake in preparation

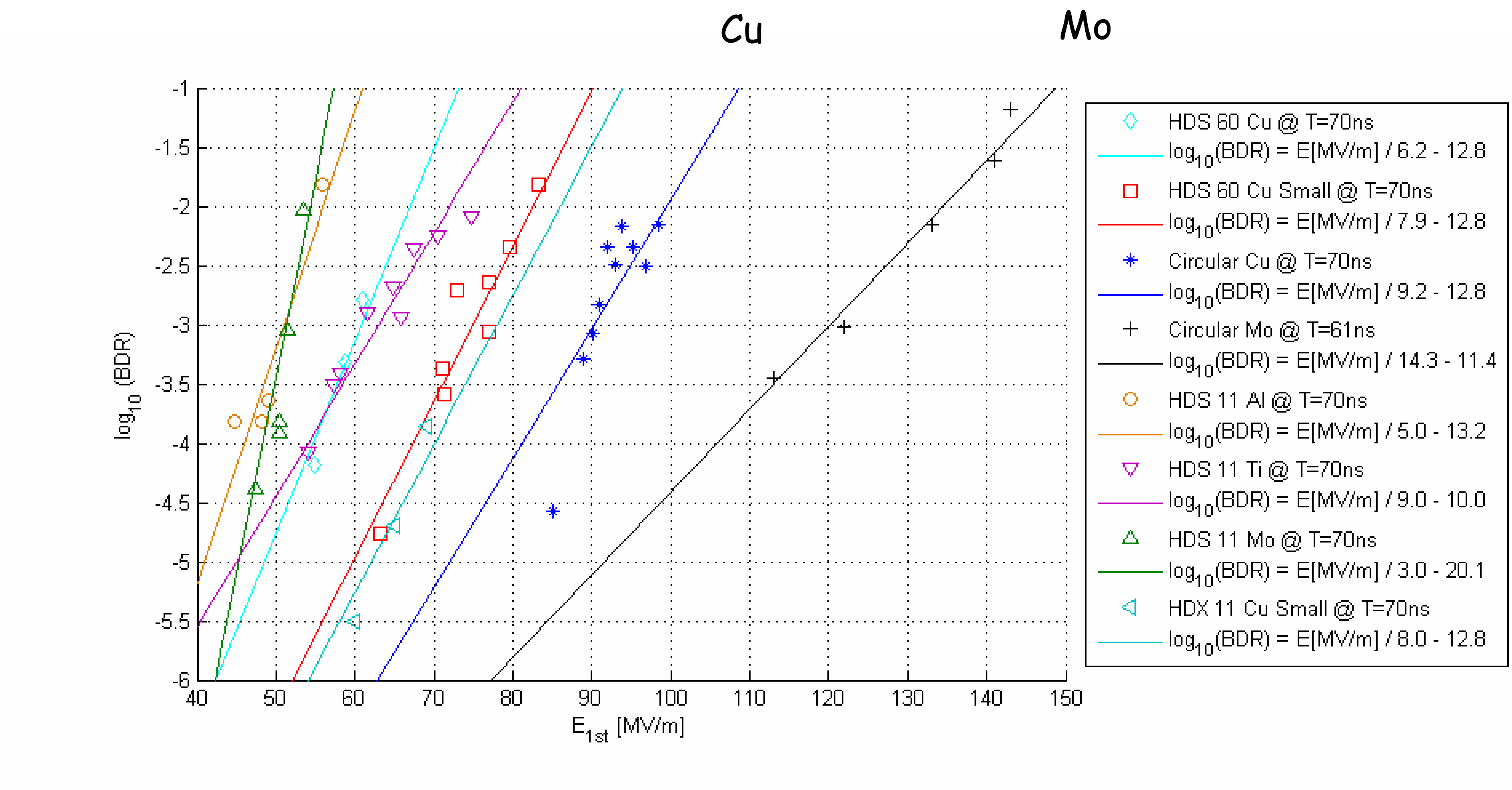




	HDS 11 Ti	HDS 60 Cu	HDS 11 Mo	HDS 11 Al
E_{1st} [MV/m] @ 70ns, BDR=10^{-3}	63	61 (97%)	51 (81%)	51 (81%)
E_{1st} [MV/m] @ 70ns, BDR=10^{-6}	36	42 (117%)	42 (117%)	36 (100%)
P_{INC} / C [MW/mm] @ 70ns, BDR=10^{-3}	1.72	1.61 (94%)	1.13 (66%)	1.13 (66%)
P_{INC} / C [MW/mm] @ 70ns, BDR=10^{-6}	0.56	0.76 (136%)	0.76 (136%)	0.56 (100%)
Slope [MV/decade]	9.0	6.2	3.0	5.0
k in $P T^k$ = CTE	-0.49	-0.50	-0.60	-0.71

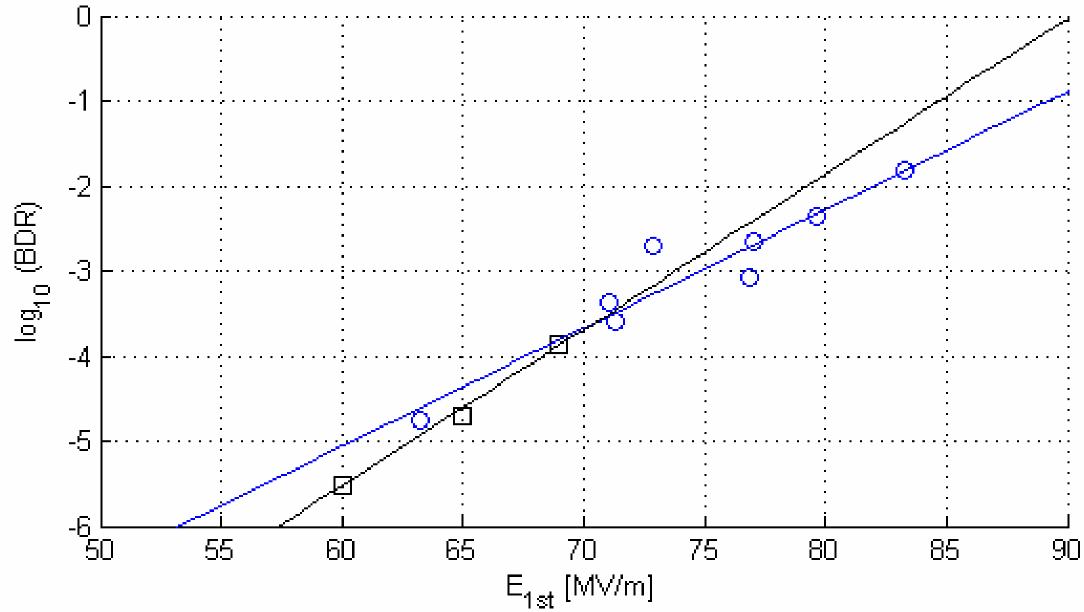


Breakdown rates @ 70 ns

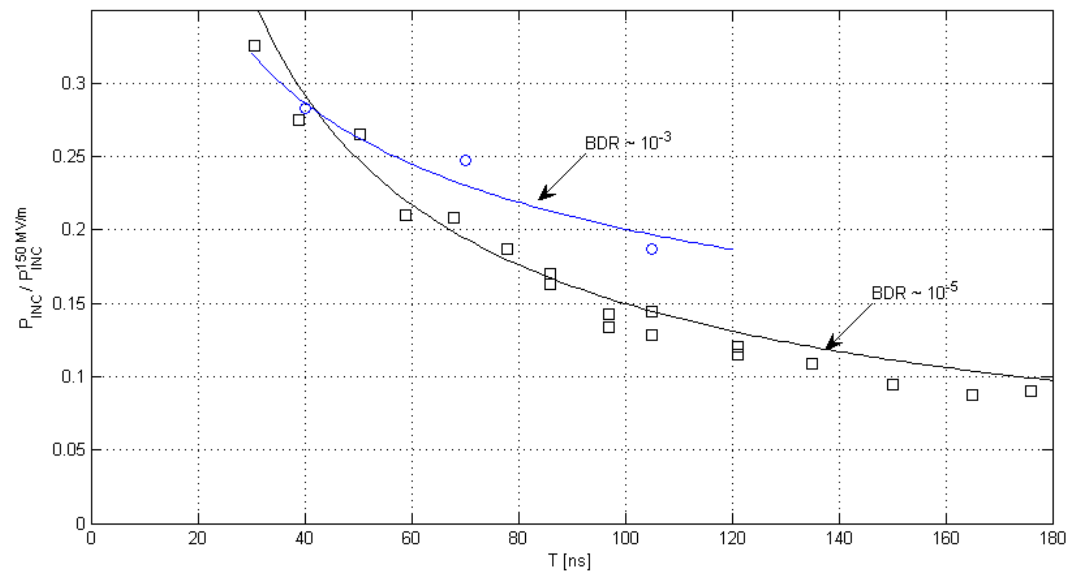


Here we see the another relative performance of Cu and Mo in maximum gradient and breakdown rate slope.

Frequency

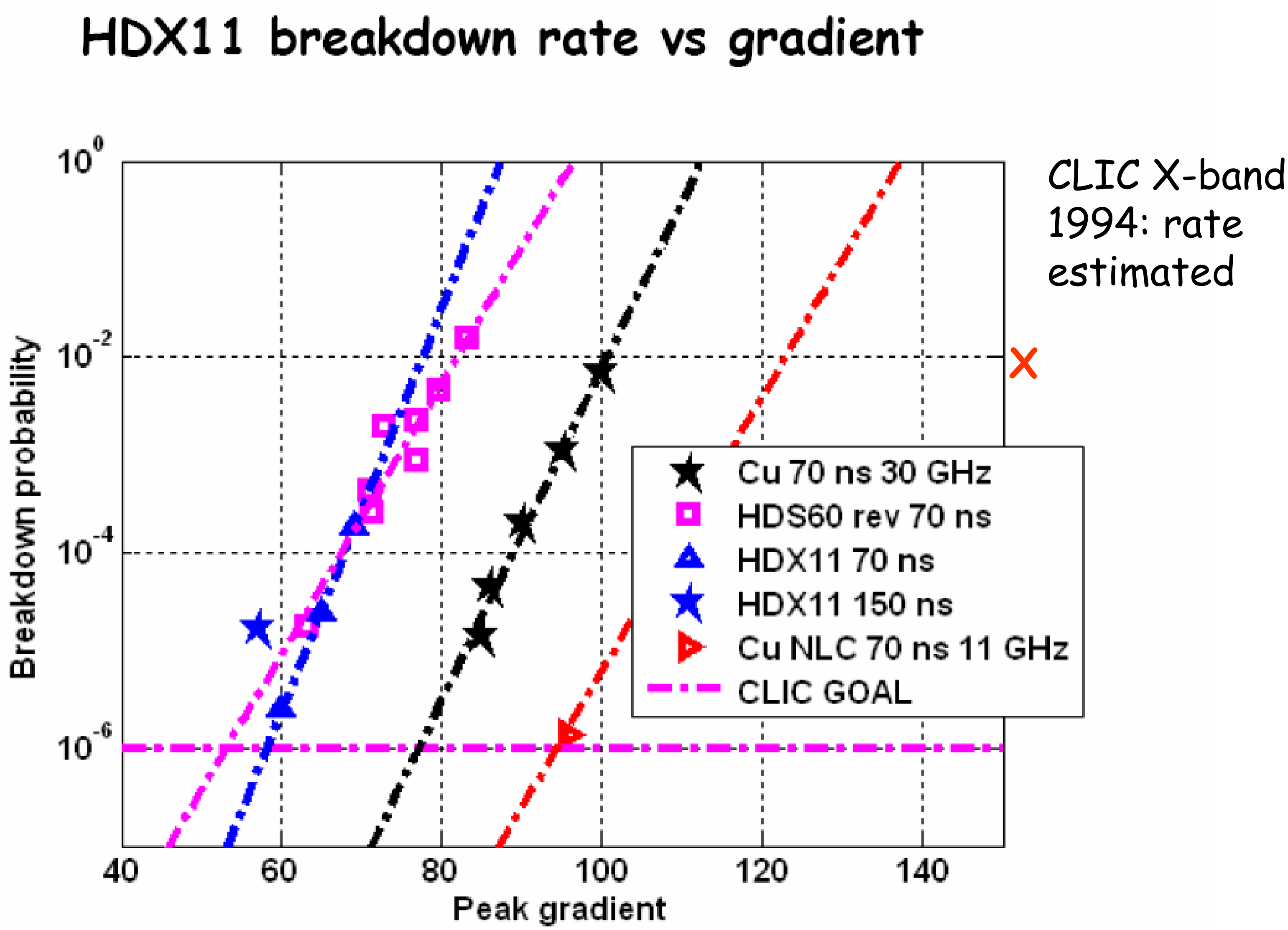


	HDS 60 Cu Small	HDX 11 Cu Small
E_{1st} [MV/m] @ 70ns, BDR=10^{-3}	75	74
E_{1st} [MV/m] @ 70ns, BDR=10^{-6}	53	57
Slope [MV/decade]	7.2	5.5
k in $P\,T^k$ = CTE	-0.39	-0.73

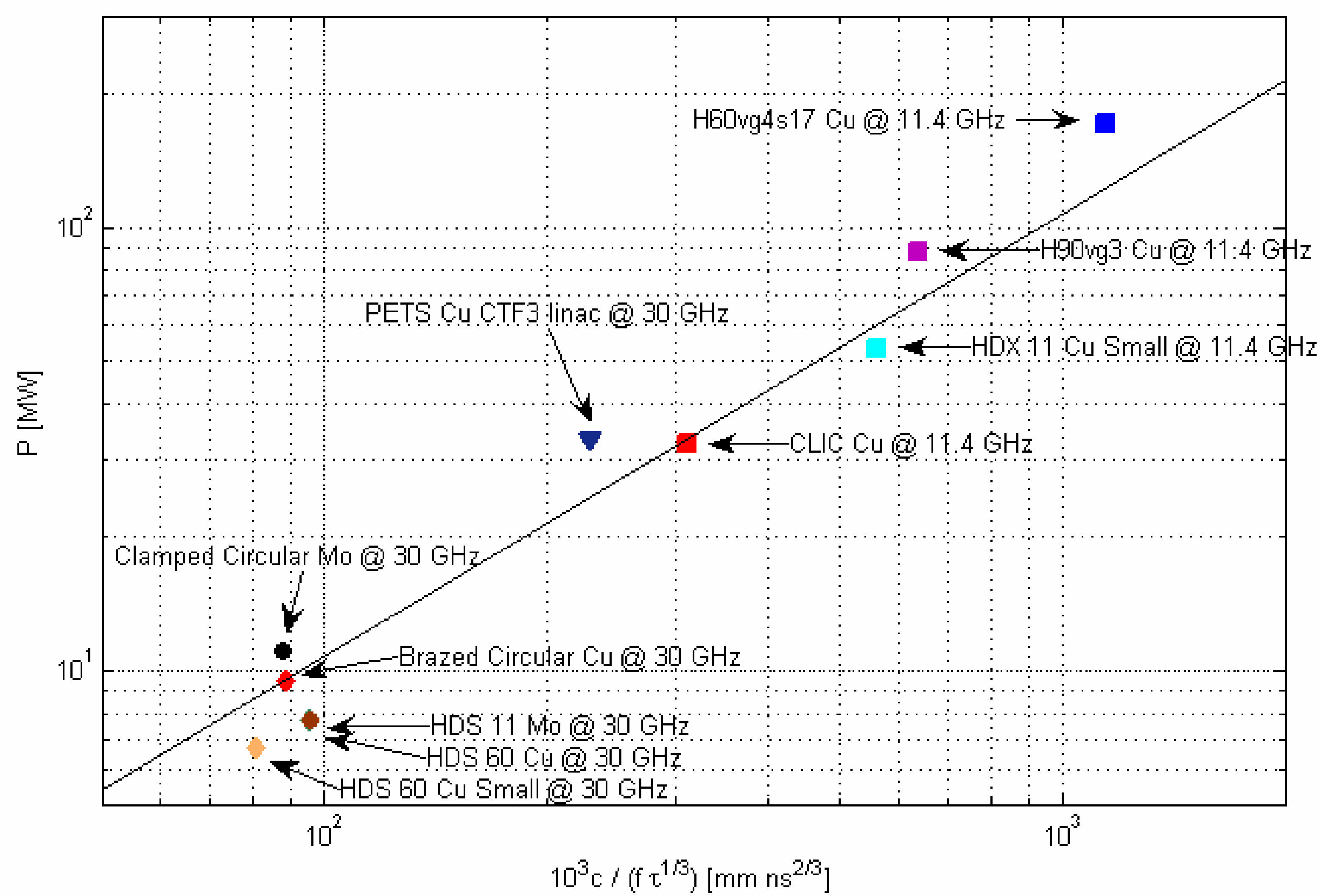


Identical scaled geometry
HDS structures

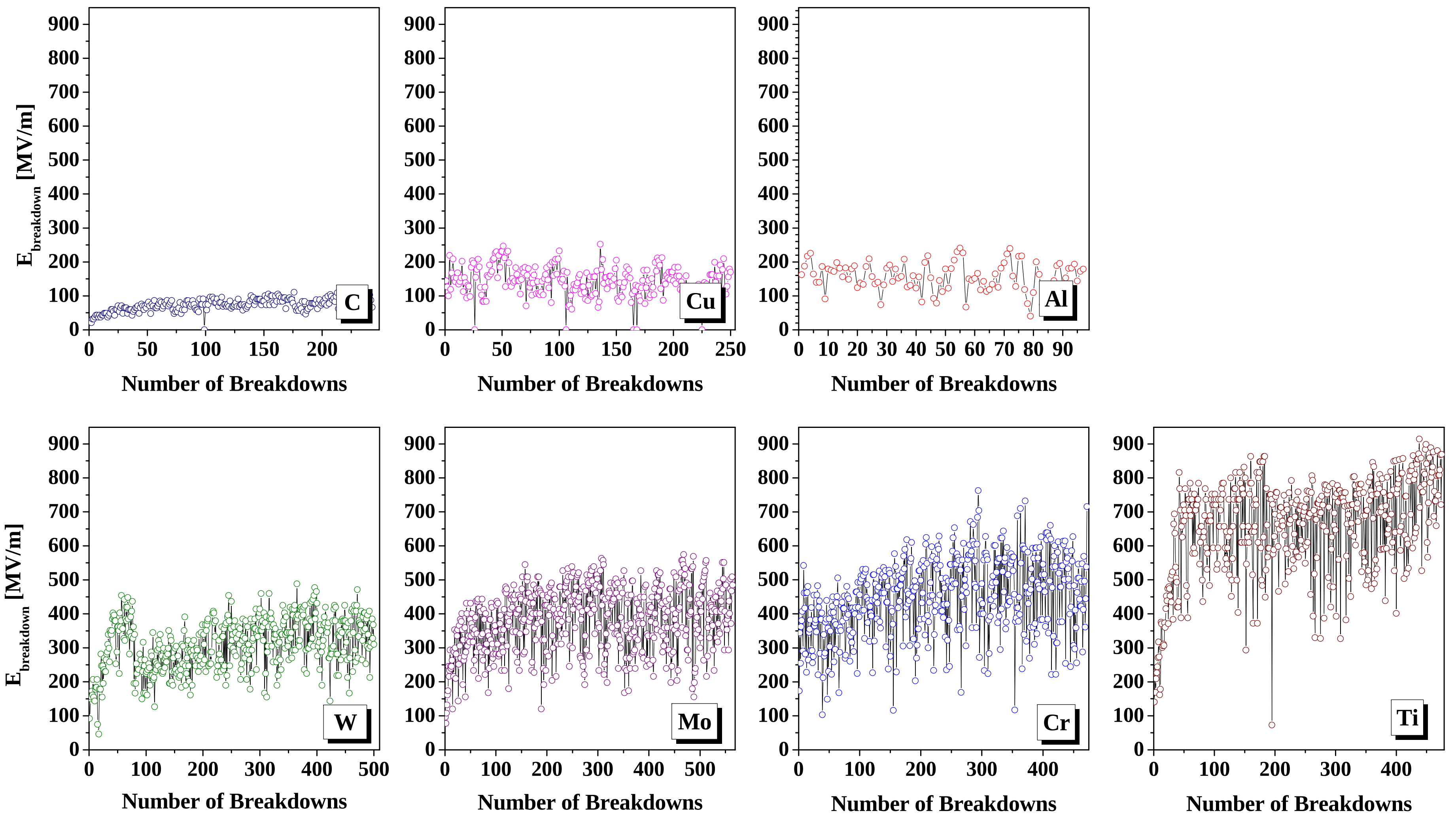
The test of short pulse operation of a recent NLC structure plus old small aperture CLIC X-band structure motivates 100 MV/m with Cu



Special topic: breakdown limit scaling



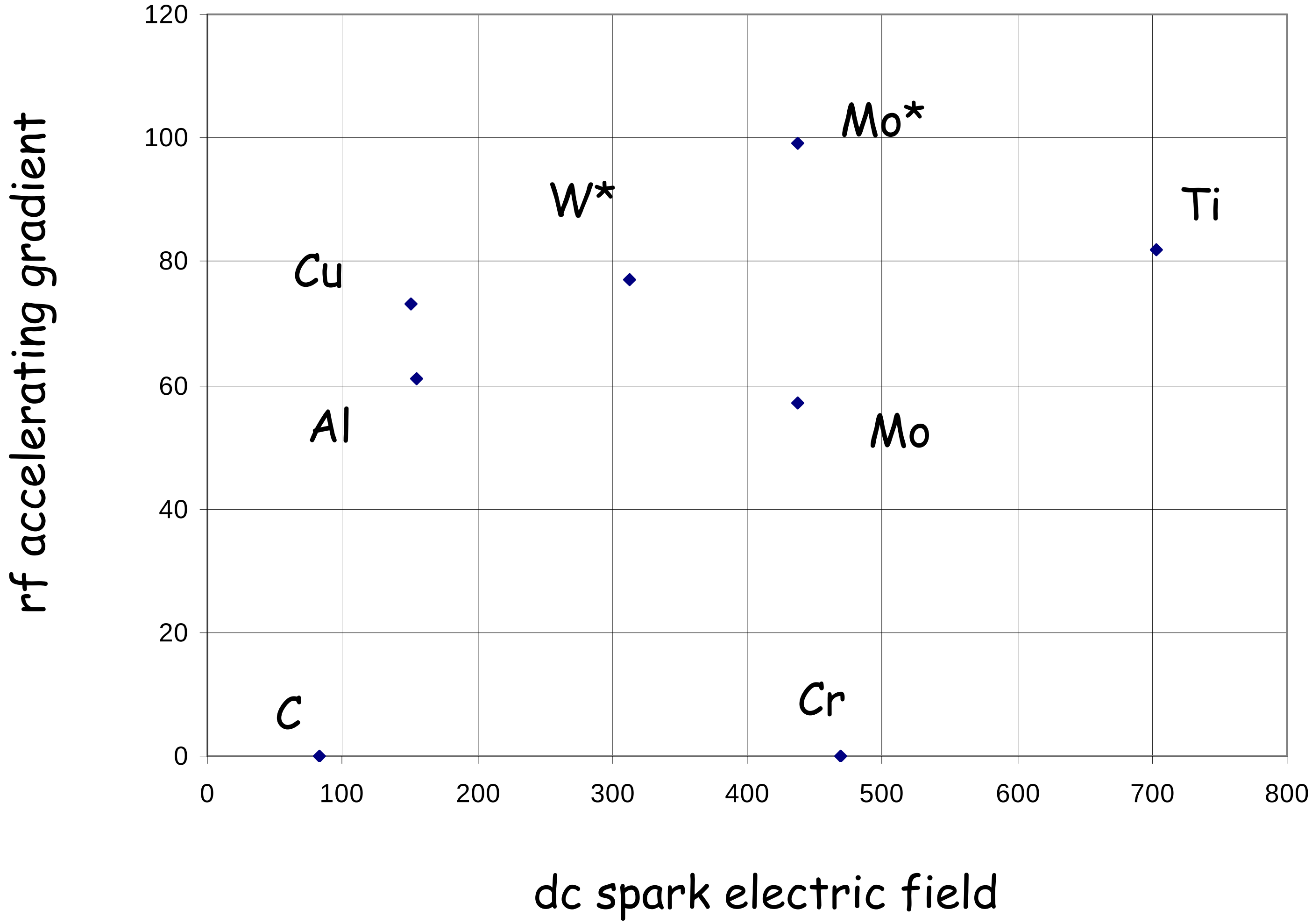
dc spark material comparison



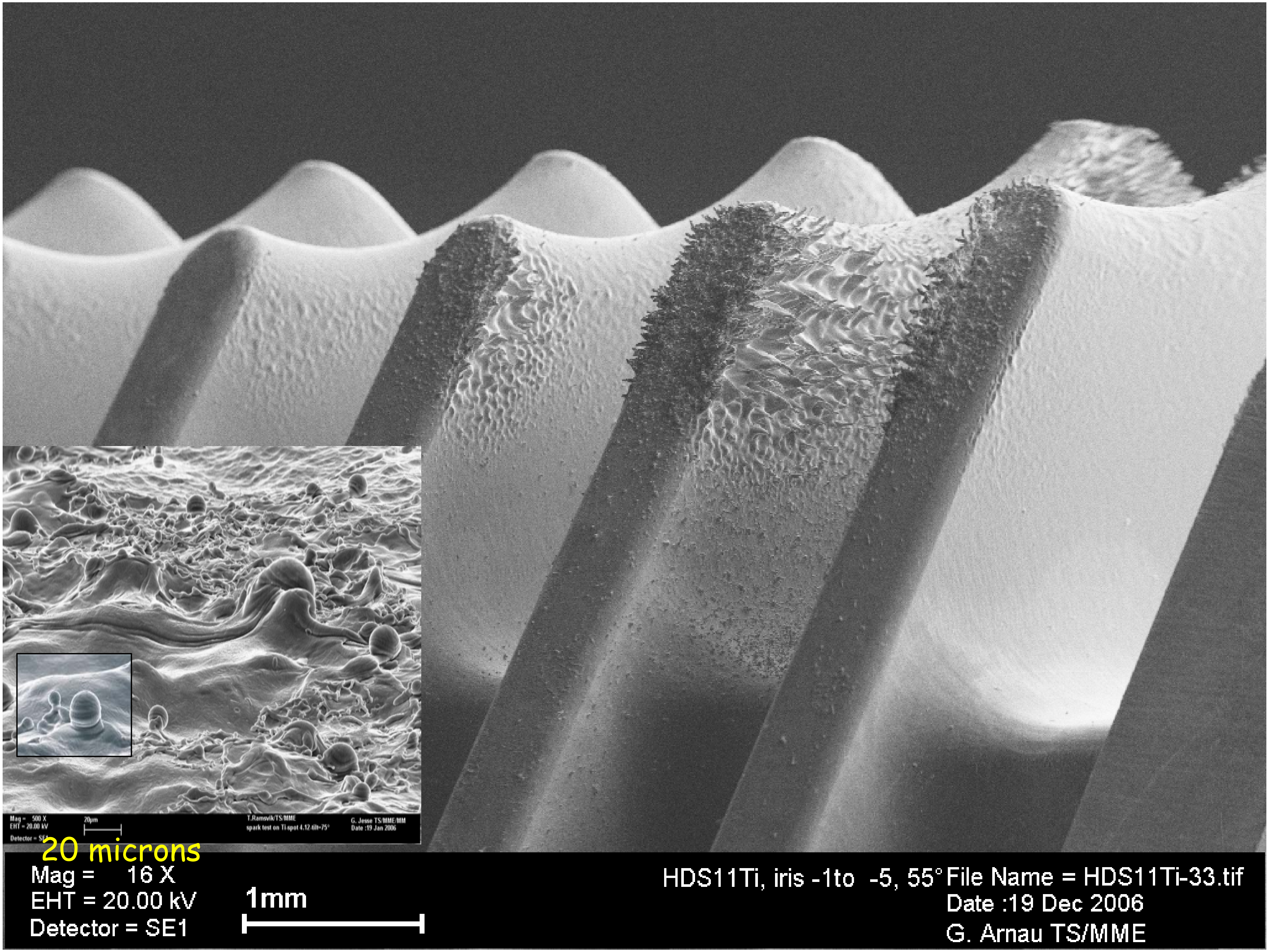
Trond Ramsvik

Thank you

HDS11 rf 10^{-1} breakdown rate vs dc spark fields



* scaled to HDS from circular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G. Jesse TS/MME/MM
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G. Arnau TS/MME

dc spark/rf comparison

Evolution of surface can overwhelm the surface electric field potential of a material.

dc spark experiments will be made at higher pulse energy to see how surface change changes.

Understanding and then avoiding the surface change we see in the first few cells, but not the later ones which have almost the same fields, powers etc., of the structures could help significantly. There are some ideas…

Breakdown rate measurements will be implemented, to make proper comparison.

So where are we?

First full year of testing in CTF3 at 30 GHz with full pulse length completed.

We commissioned and refined the whole experimental procedure – machine operation/control/installation/data acquisition/data analysis etc.

We found out and defined what to measure and how to measure it.

We tested a radically new type of structures and new materials (from an rf perspective).

We only demonstrated modest gradients,

BUT

Our ability to predict gradient from geometry is improving - rf parameters for the first HDS structures emphasized low surface fields rather than low power flow, so we will change that.

We didn't handle structures very well and we will improve handling and preparation procedures.

The first HDS damping geometry shows a power downgrade of (only!) 25% but we think we know how to improve that.

We will try to improve structure fabrication turn around time to have more generations of new ideas.

We consistently mess up the surfaces of the structures, which if this depends on more than just passing a threshold, should one day give us more gradient.

What's next in rf experiments?

30 GHz – New generation of lowered power-flow HDS structures (although we can't reach optimum X-band scaled structures due to tolerances). Quadrant and disk based circular structures to determine the power flow cost of slots/quadrants. Concentrate on Cu, Mo (one more try with Ti if we have time). Improve preparation.

X-band – For the moment two slots per year at SLAC. First, existing Mo HDX-11. Second, new optimized HDS prototype which among other things will draw on the recent tests – this should get us close to 100 MV/m. Further along, damped structures with no slot in iris (which is now accessible due to lowered gradient) in quadrant and disk form (which is now accessible due to lowered frequency). Improve preparation.

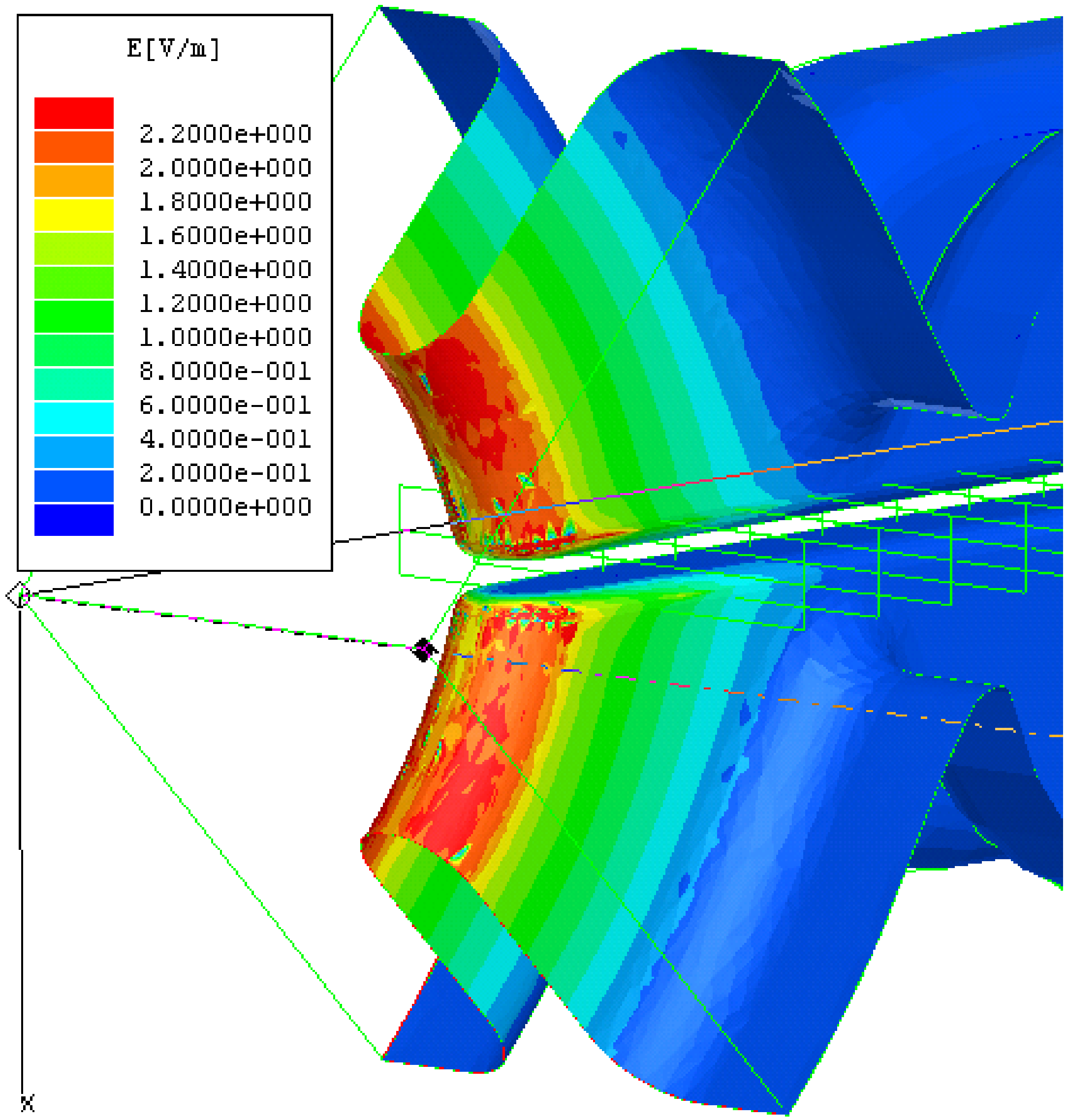
Objectives: Show solidly higher gradients. Determine and quantify most important dependencies. Shift emphasis to structures optimized to 12 GHz.

Major CLIC study objective – demonstrate the feasibility of an accelerating gradient of 100 MV/m (or higher) in a realistic structure with appropriate pulse length and breakdown rate

We struggle against two main effects – rf breakdown and fatigue from pulsed surface heating. We may also be troubled by dark currents.

For perspective the NLC had a loaded gradient of around 55 MV/m. We look for a factor of two or some tens of percent in a few different places…

Inside an accelerating structure



Quantitative model of breakdown DOES NOT EXIST

We have been given neither the time nor the money to explore all of these different effects systematically

So we have a program which in its idealized form,

Develop materials and preparation in the dc spark set up

Verify best candidates in rf experiments

Try to quantify dependence of gradient on rf geometry to choose optimum geometry

Verify best candidates in rf experiments

Get the gradient anyway even if don't really understand anything.